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A new species of *Eupithecia* Curtis (Lepidoptera, Geometridae) from the Andes of northern Chile

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Abstract. *Eupithecia copaquillaensis* **sp. nov.** (Lepidoptera, Geometridae, Larentiinae, Eupitheciini) is described and illustrated. Adults of this new species were discovered using a light trap in the Copaquilla ravine, at about 2800 m elevation on the western slope of the Andes of northern Chile. The morphology of the genitalia of *E. copaquillaensis* resembles that of *E. atacama* (Vojnits, 1985), which is also Chilean. However, the shape of the smaller cornutus and the signa in the male and female genitalia respectively enable accurate differentiation of the two species. DNA barcodes are used to associate male and female *E. copaquillaensis*.

Introduction

The widespread moth genus *Eupithecia* Curtis, 1825 (Larentiinae, Eupitheciini) is the most speciose of the family Geometridae (Lepidoptera), with more than 1300 species listed in the latest world catalogue (Parsons et al. 1999). Despite this impressive number, new species continue to be discovered in different parts of the world (e.g. Ferris 2007; Mironov and Ratzel 2012; Mironov and Galsworthy 2014; Skou et al. 2017; Seven et al. 2019).

Based on the study of the Palaearctic, Nearctic and Oriental fauna, Mironov and Galsworthy (2012) redefined *Eupithecia* and indicated a combination of some key features in the male genitalia for distinguishing the genus from the morphologically closely related genera of Eupitheciini: uncus broadest basally and hook-like distally with one or two tips, juxta "hourglass shaped" with a bilobed calcar, anterior arm of labides curved with a setose finger-like papilla at apex, and sternum VIII modified with patches of sclerotization. Furthermore, recent molecular phylogenetic studies that included Old World representatives of *Eupithecia* suggest that the genus represents a monophyletic group (Õunap et al. 2016; Brehm et al. 2019).

About a fourth of all the known species of *Eupithecia* are recorded in the Neotropical Region (Herbulot 2001). It has been suggested that the moist environments of the Andes are the most species-rich for this genus in the world (Brehm et al. 2019), based on the high species richness revealed in recent studies performed in the moist forests of the Ecuadorian Andes (Brehm et al. 2016). In contrast, the species richness of *Eupithecia* appears to be lower in the arid environments of South America (Rindge 1987).

Parsons et al. (1999) listed 61 species of *Eupithecia* with type locality in Chile; four others were added later (Parra and Ibarra-Vidal 2002; Vargas 2011). Most of the Chilean *Eupithecia* occur in the central and southern zones of the country (Vojnits 1985, 1992, 1994; Rindge 1987, 1991). In contrast, only five species have been recorded in the extremely arid environments of the northernmost part, at about 18–19°S, only one of which is known to occur in the highlands of the Andes (Rindge 1987; Vargas 2011). Adults of a second high-elevation species were recently collected in northern Chile. The examination of their genitalia revealed that the moths represent an undescribed species, whose description is provided here. DNA barcodes of one female and one male were used to confirm conspecificity.

Material and methods

The studied specimens were collected using a light trap in December, 2020 in the Copaquilla ravine (18°23'55"S, 69°37'49"W) at about 2800 m elevation on the western slopes of the Andes. Their abdomens were removed, cleared in hot KOH 10% for a few minutes, stained with Eosin Y and Chlorazol black and slide-mounted with Euparal. Images were captured with a Sony CyberShot DSC-HX200V digital camera attached to a Leica M125 stereo microscope and a Micropublisher 3.3 RTVQImaging digital camera, attached to an Olympus BX51 microscope. The distribution map was generated using SimpleMappr (Shorthouse 2010). Specimens will be deposited in the "Colección Entomológica de la Universidad de Tarapacá", Arica, Chile (IDEA).

Genomic DNA was extracted from legs of one female and one male using the QIAamp Fast DNA Tissue Kit, following the manufacturer's instructions, and sent to Macrogen Inc. (Seoul, South Korea) for purification, PCR amplification and sequencing of the barcode region (Hebert et al. 2003) using the primers (LEP-F1 and LEP-R1) and following the procedures described in Hebert et al. (2004). The sequences were aligned with ClustalW in MEGA X (Kumar et al. 2018) to search for variable sites and were analyzed using the BOLD Identification System (Ratnasingham and Hebert 2007).

Results

DNA barcodes

Two identical DNA barcode sequences of 658 base pair length were obtained, confirming the conspecificity of the male and the female analyzed (GenBank accessions MZ821652, MZ821653, respectively). The nearest match in BOLD (98.6% similarity) was with one sequence of *Eupithecia* from Antofagasta, Chile, at "Private" status. The following nearest match (93.9%) was with "Lepidoptera sp. 049 PS-2011" from Ecuador.

Eupithecia copaquillaensis sp. nov.

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Figs 1–7

Type material. ***Holotype***, male, CHILE: Chile, Parinacota, Copaquilla, 2800 m.; December 2020; light trap; H.A. Vargas leg.; IDEA-LEPI-2021-007; genitalia slide HAV-1415. Specimen and genitalia slide deposited at IDEA.

Paratypes, CHILE. Three males, IDEA-LEPI-2021-008, IDEA-LEPI-2021-009, IDEA-LEPI-2021-010, genitalia slide 1408, 1409, 1473, respectively, three females IDEA-LEPI-2021-011, IDEA-LEPI-2021-012, IDEA-LEPI-2021-013, genitalia slides 1410, 1417, 1434, respectively, same data as for holotype. Specimens and genitalia slides deposited at IDEA.

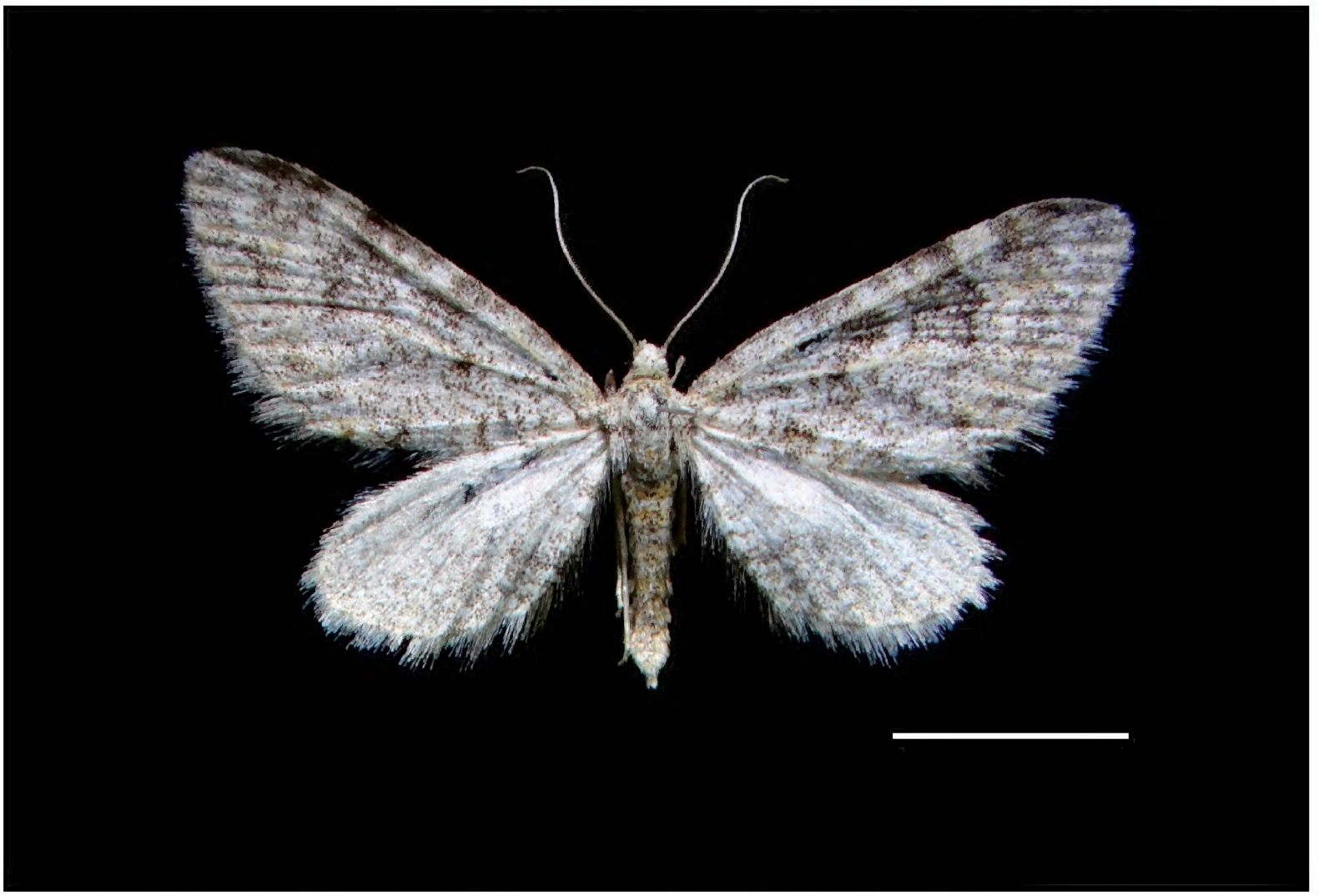


Figure 1. Male paratype of *Eupithecia copaquillaensis* sp. nov. in dorsal view. Scale bar: 5 mm.

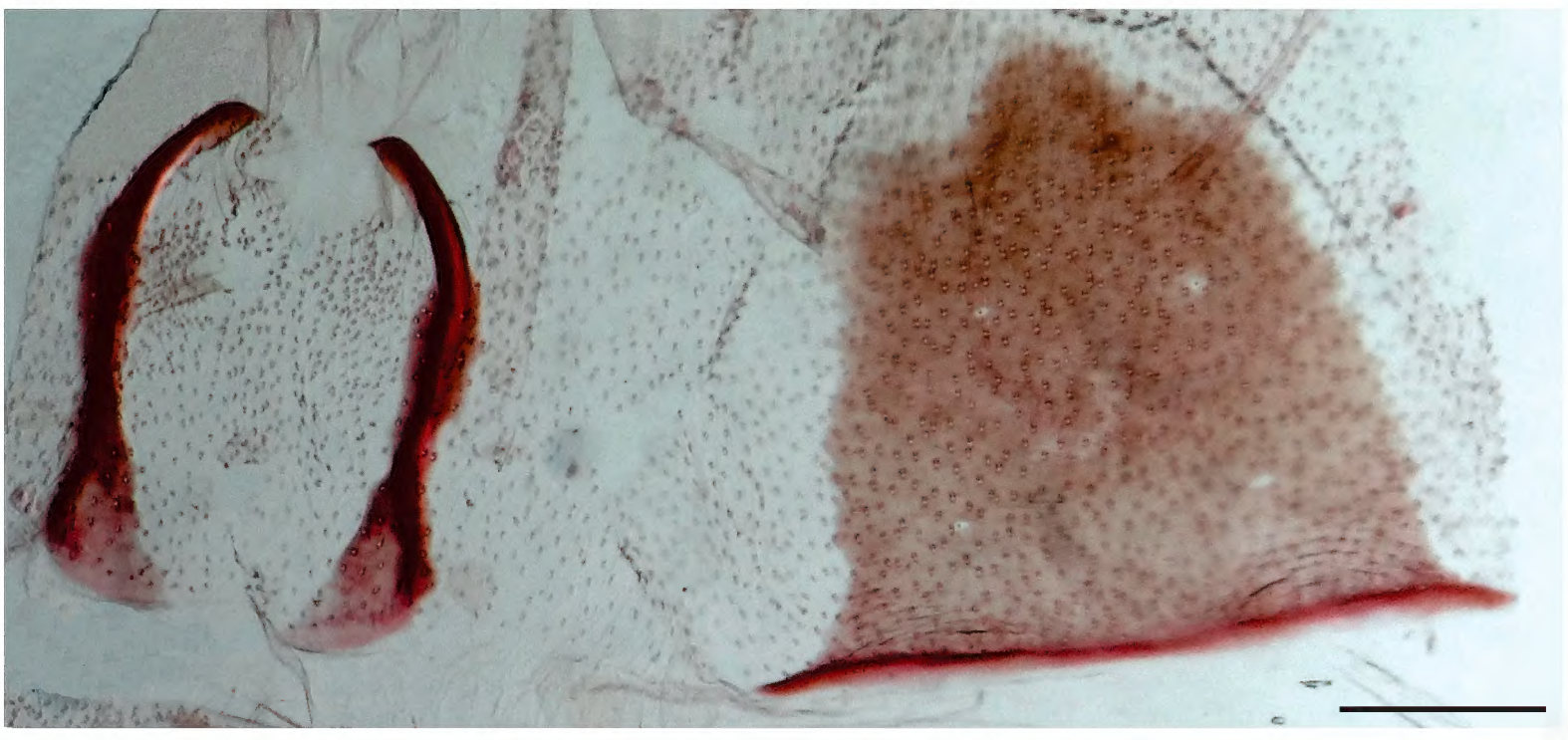
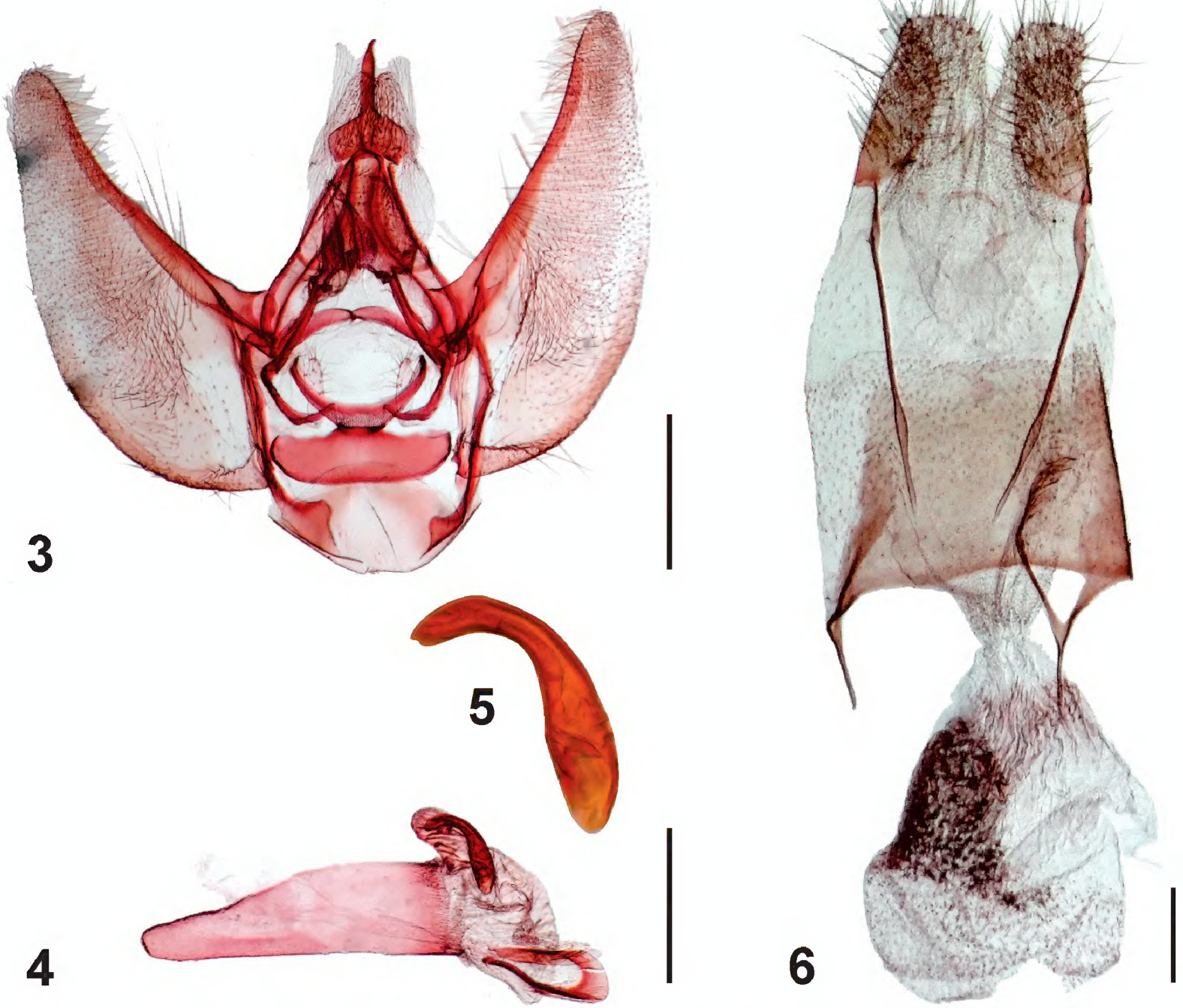


Figure 2. Male abdominal segment VIII of *Eupithecia copaquillaensis* sp. nov. Sternum (left) in ventral view; tergum (right) in dorsal view. Scale bar: 0.2 mm.

Diagnosis. The morphology of the genitalia of *E. copaquillaensis* sp. nov. (Figs 3–6) closely resembles that of *E. atacama* (Vojnits, 1985) (Figs 8–11), with type locality near Freirina village in the Huasco Province of northern Chile, also recorded in a few localities of the Coquimbo Province (Vojnits 1985). *E. atacama* was originally described in *Heteropithecia* Vojnits, 1985, a monotypic genus synonymized with *Eupithecia* by Rindge (1987). This synonymy has been followed in



Figures 3–6. Genitalia of *Eupithecia copaquillaensis* sp. nov. **3.** Male genitalia in ventral view, phallus removed; **4.** Phallus in lateral view; **5.** Smaller cornutus; **6.** Female genitalia in ventral view. Scale bar: 0.4 mm.

subsequent studies (Rindge 1991; Parsons et al. 1999), including the redefinition of *Eupithecia* by Mironov and Galsworthy (2012). The males of *E. copaquillaensis* sp. nov. and *E. atacama* have two cornuti on the vesica, the larger of which is a narrow horseshoe-like piece with asymmetrical arms. However, the smaller cornutus is sub-cylindrical and curved on the distal half in *E. copaquillaensis* sp. nov., while it is depressed, squat and concave in *E. atacama*. The females of the two species have a mainly membranous corpus bursae with small teeth-like signa. However, the signa are grouped in a dense semicircular patch in *E. copaquillaensis* sp. nov., while those of *E. atacamae* are arranged in longitudinal stripes.

Description. Male (Fig. 1). Forewing length 9.9–10.1 mm.

Head. Frons and vertex creamy white with brownish gray scattered scales. Labial palp concolorous with frons and vertex. Antenna filiform, creamy white dorsally, ciliated ventrally, cilia longer than flagellomere diameter.

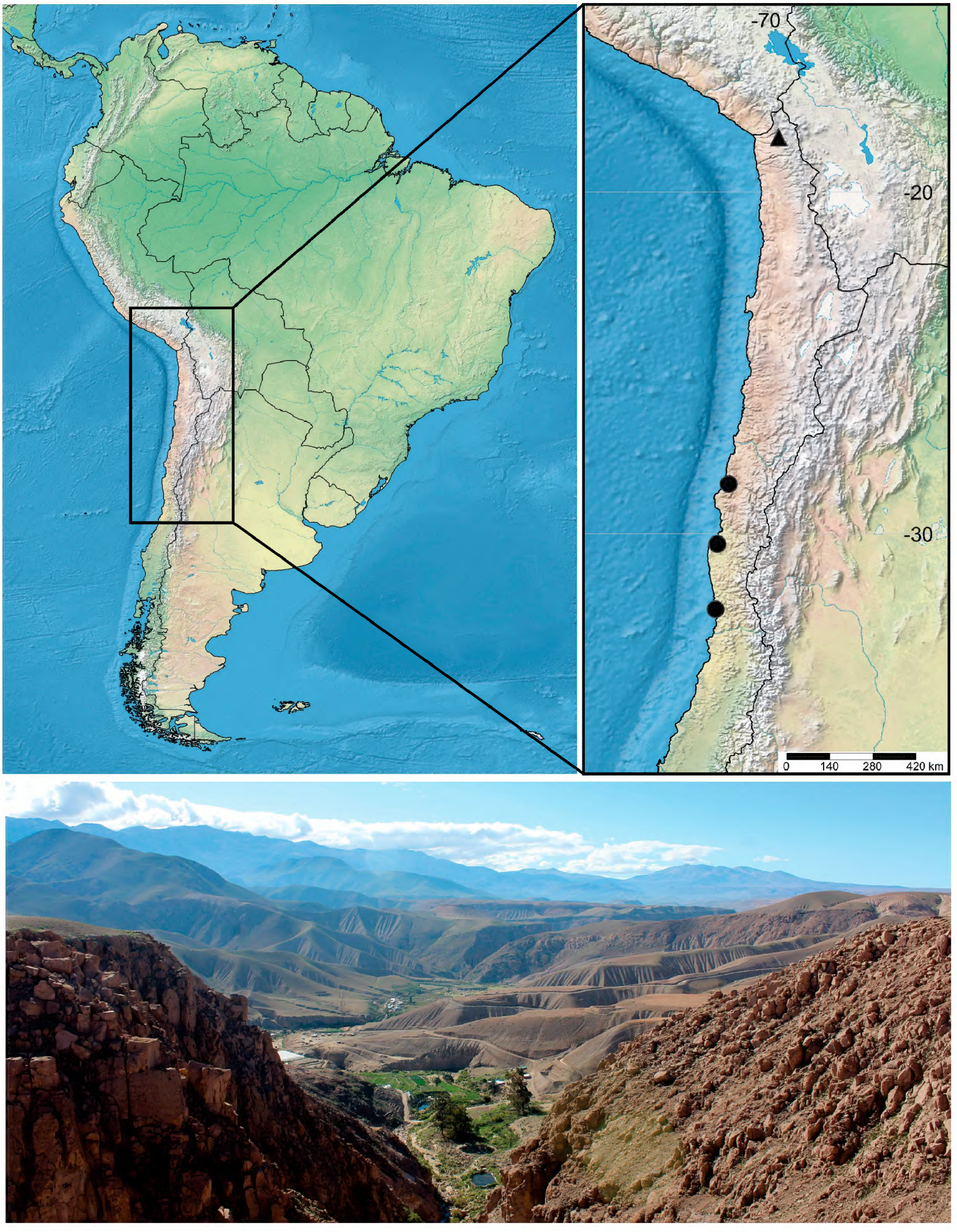


Figure 7. Geographic distribution of two morphologically close species of *Eupithecia* of northern Chile: *E. copaquillaensis* sp. nov. (triangle) and *E. atacama* (Vojnits, 1985) (circles). Lower box shows the type locality of *E. copaquillaensis* sp. nov., the Copaquilla ravine, on the western slopes of the Andes of northern Chile.

Thorax. Mainly creamy white with brownish gray and yellowish brown scattered scales. Foreleg mainly brownish gray with creamy white scattered scales. Mid- and hindleg mainly creamy white with brownish gray scattered scales; tibial spurs creamy white. Forewing mainly creamy white with abundant brownish gray and a few yellowish brown scattered scales; poorly differentiated brownish gray transverse stripes broader and darker near costal margin, narrower and lighter towards posterior margin. Hindwing mainly creamy white with poorly differentiated brownish gray transverse stripes near posterior wing margin and brownish gray scattered scales on distal half.

Abdomen. Mainly creamy white with brownish gray and yellowish brown scattered scales. Tergum VIII (Fig. 2) square-like; anterior margin straight, distinctly sclerotized, shortly projected laterally; posterior margin with short semicircular projection in the middle. Tergum VIII (Fig. 2) as two separate longitudinal rods depressed anteriorly, medially curved posteriorly.

Male genitalia (Figs 3–5). Uncus broad, depressed basally, narrow, spine-like distally, with pointed apex. Tegumen narrow, left and right parts completely separated. Saccus broadened ventrally, posterior margin broadly rounded. Juxta as a transverse ellipsoid stripe, calcar broadly U-shaped. Transtilla as a transverse stripe. Labides with anterior arm medially curved, bearing an apical finger-like papilla with short setae on distal half; posterior arm straight, bearing a semicircular slightly sclerotized papilla. Valva elongated, broader basally, narrowing distally, apex rounded, costal sclerotized band not reaching apex, sacculus slightly sclerotized. Phallus sub-cylindrical, anterior apex rounded, broadening distally; vesica with two cornuti, larger cornutus a narrow horseshoe-like piece with asymmetrical arms, smaller cornutus a sub-cylindrical piece curved on distal half.

Female. Forewing length similar to male. Antenna with cilia shorter than flagellomere diameter. Wings slightly lighter than those of male, with less brownish gray and more yellowish brown scales.

Female genitalia (Fig. 6). Papilla analis lobe-like, slightly sclerotized near anterior margin, with hair-like setae. Posterior apophysis narrow, rod-shaped, about twice the length of papilla analis. Anterior apophysis narrow, rod-shaped, about half the length of papilla analis; ventral arm about same length as papilla analis, distally depressed and slightly broadened. Antrum broad, membranous. Ductus bursae short, membranous. Corpus bursae mainly membranous, with longitudinal striations, small teeth-like signa grouped in a dense semicircular patch. Ductus seminalis at apex of a narrow, finger-like appendix bursae near the base of corpus bursae.

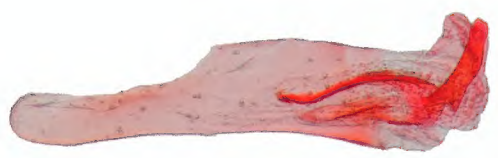
Etymology. The specific name is derived from the type locality.

Distribution (Fig. 7). Based on the type material, *E. copaquillaensis* sp. nov. is known only from the type locality, the Copaquilla ravine (18°23'55"S, 69°37'49"W), at about 2800 m elevation on the western slopes of the arid Andes of northern Chile. The high similarity (98.6%) of the barcode of *E. copaquillaensis* sp. nov. to a congeneric sequence from Antofagasta, Chile found in BOLD suggests a broader geographic range, reaching to about 400 km south of the type locality. However, the exact sampling site of the BOLD sequence is unknown.

Biology. Adults of *E. copaquillaensis* sp. nov. were collected using a light trap in December 2020. Host plants remain unknown.

Discussion

Eupithecia copaquillaensis sp. nov. is the second species of the genus known to occur in the arid highlands of the western slopes of the Andes of the northernmost part of Chile. The only conspecific previously recorded in the same area is *E. tarapaca* Rindge, 1987, whose larvae feed on



Figures 8–11. Genitalia of *Eupithecia atacama* (Vojnits, 1985). **8.** Male genitalia in ventral view, phallus removed; **9.** Phallus in lateral view; **10.** Smaller cornutus; **11.** Female genitalia in ventral view. Scale bar: 0.4 mm.

flower buds of *Balbisia microphylla* (Phil.) Reiche (Vivianiaceae) (Vargas 2016). However, the two species are easily separated based on morphology, because in the latter the male sternum VIII is a narrow piece with two short apical arms, the larger cornutus is a broad piece slightly shorter than the phallus and the smaller cornutus is a C-shaped piece, all of which remarkably contrast with the morphological pattern of *E. copaquillaensis* sp. nov.

Rindge (1987) arranged the species of *Eupithecia* of Chile in two Sections, namely 1 and 2, with the latter subdivided into four Groups named A to D, based on the morphology of the male segment VIII and male and female genitalia. The tergum fully sclerotized and the sternum as two separate longitudinal rods in the male segment VIII, the elongated valva, uncus with single apex and vesica with two cornuti in the male genitalia, and the corpus bursae with longitudinal striations in the female genitalia suggest that *E. copaquillaensis* sp. nov. is related to the species of Section 1, in which Rindge (1987, 1991) included the morphologically close *E. atacama* and four others: *E. atacamaensis* Rindge, *E. guayacanae* Rindge, 1991, *E. osornoensis* Rindge, 1987 and *E. seatacama* Rindge, 1987. However, the monophyly of this species group, as well as the phylogenetic relationships of all the Neotropical fauna of *Eupithecia*, must be reassessed using modern procedures.

Perhaps discouraged by the extremely arid conditions, surveys for geometrid moths have been scarce on the western slopes of central Andes. For instance, in the case of *Eupithecia*, the holotype

of *E. tarapaca* was until a few years ago the only specimen reported in the scientific literature from above 3000 m in the northernmost part of Chile (Vojnits 1985, 1992, 1994; Rindge 1987, 1991). In accordance with recent additions to other genera of Geometridae (Palacios et al. 2020; Vargas et al. 2020; Vargas 2021), the discovery of *E. copaquillaensis* sp. nov. confirms the need for further studies to characterize better the overlooked fauna of geometrid moths harbored by the high elevation environments of central Andes.

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